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DESCRIPTION

~~HEAT EXCHANGER, METHOD FOR MANUFACTURING HEAT EXCHANGER, TUBE~~ CONNECTING STRUCTURE FOR HEAT EXCHANGER HEADER TANK, GAS COOLER USING SUPERCRITICAL REFRIGERANT, AND REFRIGERATION SYSTEM

Priority is claimed to Japanese Patent Application No. 2002-240927 filed on August 21, 2002 and U.S. Provisional Patent Application No. 60/407,945 filed on September 5, 2002, the disclosure of which are incorporated by reference in their entireties.

Cross Reference to Related Applications

This application is an application filed under 35 U.S.C. §111(a) claiming the benefit pursuant to 35 U.S.C. §119(e)(1) of the filing date of U.S. Provisional Application No. 60/407,945 filed on September 5, 2002 pursuant to 35 U.S.C. §111(b).

Technical Field

The present invention relates to a heat exchanger, etc. for use in automobile air-conditioners, household air-conditioners, electric device coolers and the like having a refrigeration cycle using CO_2 refrigerant.

Background Art

Since Freon refrigerant used as refrigerant for air-

conditioning apparatuses is an ozone depleting substance and a greenhouse substance, a refrigeration cycle using a carbon dioxide (CO_2), which exists in nature, as refrigerant has been drawn attention as defreonization air-conditioning techniques.

In a refrigeration cycle using Freon refrigerant, since the refrigerant becomes a liquid-gas mixed state during the cooling (heat rejection) process at the high-pressure circuit side in a condenser, the refrigerant will be maintained at the condensation temperature in almost the entire region of the condensing passages. Accordingly, by employing the so-called cross-flow type heat exchanger in which condensing passages are disposed in a plane perpendicular to the cooling air introducing direction in a meandering manner so as to introduce the cooling air of a constant temperature throughout the entire condensing passages, the temperature difference between the refrigerant and the cooling air can be fully secured in the entire condensing passages, resulting in high heat exchanging efficiency.

To the contrary, in a refrigeration cycle using CO_2 refrigerant, the CO_2 refrigerant is operated in a supercritical state in which no phase change occurs during the heat rejection process at the high pressure circuit side. Therefore, the refrigerant temperature deteriorates gradually as it goes from the entrance side of the heat rejection passages toward the exit side thereof. However, in the aforementioned cross-flow type heat exchanger, a cooling air of a constant temperature is introduced in the entire region of the heat rejection passages. Thus, in cases

where this cross-flow type heat exchanger is used as a gas cooler (heat rejection device) having a refrigeration cycle using CO_2 refrigerant, the temperature difference between the refrigerant and the cooling air becomes uneven in the heat rejection passages such that the temperature difference becomes larger at the inlet side of the heat rejection passages and smaller at the outlet side thereof. This makes it difficult to obtain high heat exchanging efficiency.

To cope with this problem, by employing the so-called counter flow type heat exchanger in which heat rejection passages are disposed in a meandering manner so as to extend in a direction opposite to the cooling air introducing direction so that the cooling air temperature at the exit side of the heat rejection passage is lower than that at the inlet side thereof, an enough temperature difference between the refrigerant and the cooling air can be secured in the entire heat rejection passages, resulting in improved heat exchanging efficiency.

This kind of conventional counter flow type heat exchanger is disclosed by, for example, Japanese Unexamined Laid-open Utility Model Publication No. 57-66389 and Japanese Unexamined Laid-open Patent Publication No. 10-288476.

In these heat exchangers, a plurality of heat exchanging tubes are disposed in parallel and arranged in the up and down direction with both ends thereof connected to a pair of header tanks disposed along the up and down direction in fluid communication. The heat exchanging tube has a flat configuration with a wide width, and

is provided with a plurality of refrigerant passages extending in the longitudinal direction of the tube and arranged in the widthwise direction (fore and aft direction) of the tube. On the other hand, in one of the header tanks, a partitioning plate is provided along the longitudinal direction (in the up and down direction). Thus, the inside space of the header tank is divided into a front half space and a rear half space by the partitioning plate. The rear half space is communicated with the rear half side of the refrigerant passages of heat exchanging tubes, while the front half space is communicated with the front half side of the refrigerant passages of the heat exchanging tubes.

Thus, the refrigerant flowed into the rear half space of one of the header tanks passes through the rear half side of the refrigerant passages (first pass) of the heat exchanging tubes and flows into in the other of the header tanks. Then, the refrigerant passes through the front half side of the refrigerant passages (second pass) of the heat exchanging tubes to be introduced into the front half space of the one of header tanks and then flows out. In this way, the refrigerant passes through the first and second passes in this order, while the cooling air introduced from the front side of the heat exchanger passes through the second and first passes in this order, whereby the refrigerant exchanges heat with the cooling air.

In the refrigeration cycle using CO_2 refrigerant, however, the refrigerant working pressure at the high pressure circuit side becomes higher as much as about 10 times as compared with a

refrigeration cycle using Freon refrigerant. Therefore, in the aforementioned conventional heat exchanger with a partitioning plate in the header tank, the mounting strength and the positioning accuracy of the partitioning plate become inadequate, causing insufficient pressure resistance, which deteriorates the air-tightness at the joint portions of the partitioning plate. Especially, in a quasi counter flow type heat exchanger in which a plurality of refrigerant passages provided in a flat heat exchanging tube are grouped into a plurality of passes, it becomes difficult to fully secure the air-tightness at the joint portions of the partitioning plate and the heat exchanging tube end portions. This may cause an introduction of the refrigerant into the adjacent passages, which deteriorates heat exchange performance.

It is an object of the present invention to solve the problems of the aforementioned conventional techniques and provide a heat exchanger capable of obtaining sufficient pressure resistance, preventing refrigerant leakage and improving heat exchange performance. It is another object of the present invention to provide a tube connecting structure of a heat exchanger header tank and a refrigeration system.

Disclosure of Invention

According to the first aspect of the present invention, a heat exchanger, comprises:

a pair of header tanks; and

a plurality of heat exchanging tubes disposed between the pair

of header tanks and arranged in parallel in a header tank longitudinal direction,

wherein each of the header tanks is provided with one or more partitioning walls integrally formed in each of the header tanks and extended in the header tank longitudinal direction, whereby a plurality of tank portions divided by the one or more partitioning walls and extended in the header tank longitudinal direction are formed and arranged in parallel in a header tank widthwise direction, wherein a refrigerant turning communication aperture for communicating adjacent tank portions is formed in a prescribed partitioning wall,

wherein each of the heat exchanging tubes has a flat configuration having a width dimension larger than a height dimension, and is provided with a plurality of refrigerant passages extended in a tube longitudinal direction and arranged in parallel in a tube widthwise direction,

wherein both ends of each of the heat exchanging tubes are communicated with the pair of header tanks so that the refrigerant passages of each of the heat exchanging tubes are grouped in the tube widthwise direction in accordance with each tank portion of the header tanks, to thereby form a plurality of passes arranged in parallel in the tube widthwise direction, and

wherein refrigerant introduced into a first tank portion of one of the header tanks is introduced into a first tank portion of the other of the header tanks via a first pass, then the refrigerant is introduced into a second tank portion of the other

of the header tanks via the refrigerant turning communication aperture, and thereafter the refrigerant is introduced into a second tank portion of the one of the header tanks via a second pass.

In the heat exchanger according to the first aspect of the present invention, since the heat exchanger has the co-called counter flow type refrigerant circuit in which refrigerant passes in a meandering manner against the introducing direction of cooling air, an appropriate temperature difference between the refrigerant and the cooling air such as CO_2 can be secured through all of the passes, causing efficient heat exchanging, which results in excellent heat exchanging performance.

Furthermore, since the partitioning wall is integrally formed in the header tank, enough air-tightness especially at the partitioning wall portion can be secured, resulting in enough durability. Furthermore, refrigerant mixture due to leaking can be prevented assuredly, which further improved heat exchanging performance.

In the first aspect of the present invention, it is preferable that each of the header tanks is an integrally formed article formed by extrusion processing or drawing processing, or that the heat exchanging tube is an integrally formed article formed by extrusion processing or drawing processing.

In these cases, the pressure resistance can be further improved and the manufacturing efficiency can be improved by employing extrusion processing or drawing processing which are suitable for mass production.

Furthermore, in the first aspect of the present invention, it is preferable that a plurality of tube insertion apertures communicating with the tank portions are provided at an inner side surface of each of the header tanks at certain intervals in the header tank longitudinal direction, and that refrigerant passages at end portions of the heat exchanging tubes are communicated with corresponding tube insertion apertures.

In this case, the end portions of the heat exchanging tubes can be brazed to the header tanks in a stable manner, which can further improve the pressure resistance while preventing poor joining at the joined portions assuredly.

Furthermore, in the first aspect of the present invention, it is preferable that end portions of each of the heat exchanging tubes are provided with one or more cutout portions corresponding to the one or more partitioning walls and that the end portions of each of the heat exchanging tubes are inserted into the tube insertion apertures with the one or more partitioning walls fitted in the one or more cutout portions.

In this case, since the cutout portions of the tube end portion is engaged with the partitioning wall, the positioning of the tube end portion in the insertion direction and in a direction perpendicular to the insertion direction can be performed correctly. Thus, the tube insertion can be performed easily. Furthermore, enough joining area of the tube to the header tank can be secured, enabling a stable joining status, which can prevent poor joining more assuredly and further improve the pressure resistance.

Furthermore, in the first aspect of the present invention, it is more preferable that one or more regions of each of the heat exchanging tubes corresponding to the one or more cutout portions are formed to be one or more non-passage areas in which no refrigerant passage exists and that regions of each of the heat exchanging tubes not corresponding to the one or more cutout portions are formed to be passage areas in which the refrigerant passages exist.

In this case, it is possible to effectively prevent such a problem that cutout portions are formed in passages of the heat exchanger.

Furthermore, in the first aspect of the present invention, it is more preferable that the refrigerant turning communication aperture formed in the partitioning wall of the other of the header tanks is configured by a cut aperture formed in an inside surface of the other of the header tanks.

In this case, the refrigerant turning communication aperture can be assuredly formed by such a simple operation that cutting is performed to the inside surface side of the header tank, which in turn can further improve the productive efficiency of the heat exchanger itself.

Furthermore, in the first aspect of the present invention, it is more preferable that each of the header tanks is provided with a joining plate joined to an inner side surface thereof, wherein a plurality of tube insertion apertures are provided in the joining plate at certain intervals in a joining plate longitudinal direction,

and that end portions of each of the heat exchanging tubes are inserted into corresponding tube insertion apertures to be communicated with the header tanks.

Furthermore, in the first aspect of the present invention, in cases where the refrigerant turning communication aperture is configured by a cut aperture formed in an inside surface of the header tank, the aperture can be formed by simply performing cutting to the inside surface of the header tank.

In this case, the rigidity of the tank itself can be improved, which further improves the durability of the entire heat exchanger. Furthermore, the sealing processing of the refrigerant turning communication aperture formed in the inside surface of the header tank can be performed easily and assuredly, which in turn can further improve the productive efficiency of the heat exchanger itself.

Furthermore, as explained above, since the first aspect of the present invention specifies the so-called counter flow type heat exchanger which is excellent in pressure resistance, the heat exchanger according to the first aspect of the present invention can be preferably used as a heat exchanger using CO_2.

That is, in the first aspect of the present invention, it is preferable that CO_2 is used as the refrigerant.

The aforementioned preferable structures can be employed as preferable structures of the below mentioned second to sixth aspects of the present invention.

The second aspect of the present invention specifies an embodiment of a manufacturing process for manufacturing the

aforementioned heat exchanger according to the first aspect of the present invention.

According to the method for manufacturing a heat exchanger of the second aspect of the present invention, the method comprises:

preparing a pair of header tanks, wherein each of the header tanks is provided with one or more partitioning walls integrally formed in each of the header tanks and extended in a header tank longitudinal direction, whereby a plurality of tank portions divided by the one or more partitioning walls and extended in the header tank longitudinal direction are formed so as to be arranged in parallel in a header tank widthwise direction, wherein a refrigerant turning communication aperture for communicating adjacent tank portions is formed in predetermined partitioning walls;

preparing a plurality of heat exchanging tubes, wherein each of the heat exchanging tubes has a flat configuration having a width dimension larger than a height dimension, and is provided with a plurality of refrigerant passages extended in a tube longitudinal direction and arranged in parallel in a tube widthwise direction; and

forming a plurality of passes arranged in parallel in the tube widthwise direction by communicating both ends of each of the heat exchanging tubes with the pair of header tanks so that the refrigerant passages of each heat exchanging tubes are grouped into the plurality of passes in the tube widthwise direction in accordance with each of the tank portions of the header tank,

whereby refrigerant introduced into a first tank portion of one of the header tanks is introduced into a first tank portion of the other of the header tanks via a first pass, then the refrigerant is introduced into a second tank portion of the other of the header tanks via the refrigerant turning communication aperture, and thereafter the refrigerant is introduced into a second tank portion of the one of the header tanks via a second pass.

In the second aspect of the present invention, since the second aspect of the present invention specifies an embodiment of a manufacturing process for manufacturing the aforementioned heat exchanger according to the first aspect of the present invention, a heat exchanger having the same effects as mentioned above can be manufactured.

In the second aspect of the present invention, it is preferable that at least one of the header tanks is provided, at its inner surface side, with a plurality of tube insertion apertures for communicating end portions of the heat exchanging tubes and the refrigerant turning communication aperture, and that the tube insertion apertures and the refrigerant turning communication aperture are formed simultaneously by cutting processing.

In this case, the number of processing operations can be reduced, resulting in further improved product efficiency.

The third aspect of the present invention specifies a heat exchanger which can be preferably used as a heat exchanger using CO_2 refrigerant among heat exchangers according to the first aspect of the present invention.

According to the third aspect of the present invention, a heat exchanger, comprises:

a pair of header tanks; and

a plurality of heat exchanging tubes disposed between the pair of header tanks and arranged in a header tank longitudinal direction,

wherein each of the header tanks is provided with three partitioning walls integrally formed in each of header tanks and extended in the header tank longitudinal direction, whereby a first tank portion to a fourth tank portion divided by the partitioning walls and extended in the header tank longitudinal direction are formed so as to be arranged in parallel in a header tank widthwise direction, wherein a refrigerant turning communication aperture for communicating adjacent tank portions is formed in a partitioning wall partitioning the second tank portion and the third tank portion of the one of the header tanks, a partitioning wall partitioning the first tank portion and the second tank portion of the other of the header tanks and a partitioning wall partitioning the third tank portion and the fourth tank portion of the other of the header tanks,

wherein each of the heat exchanging tubes has a flat configuration having a width dimension larger than a height dimension, and is provided with a plurality of refrigerant passages extended in a tube longitudinal direction and arranged in parallel in a tube widthwise direction,

wherein both ends of each of the heat exchanging tubes are

communicated with the pair of header tanks so that the refrigerant passages of each of the heat exchanging tubes are grouped in the tube widthwise direction in accordance with each tank portion of the header tanks, to thereby form a first to fourth passes arranged in parallel in the tube widthwise direction, and

wherein refrigerant introduced into the first tank portion of one of the header tanks passes through the first to fourth passes in turn and then introduced into the fourth tank portion of the one of the header tanks.

Since the third aspect of the present invention specifies a heat exchanger which can be preferably used as a heat exchanger using CO_2 refrigerant among heat exchangers according to the first aspect of the present invention, the aforementioned effects can be obtained.

The fourth aspect of the present invention specifies a tube connecting structure for a header tank of a heat exchanger which is a principal portion of the heat exchanger according to the first aspect of the present invention.

According to the fourth aspect of the present invention, a tube connecting structure for a header tank of a heat exchanger comprising a pair of header tanks and a plurality of heat exchanging tubes disposed between the pair of header tanks and arranged in a header tank longitudinal direction,

wherein each of the header tanks is provided with one or more partitioning walls integrally formed in each of header tanks and extended in the header tank longitudinal direction, whereby a

plurality of tank portions divided by the partitioning walls and extended in the header tank longitudinal direction are formed so as to be arranged in parallel in a header tank widthwise direction, wherein tube insertion apertures communicating with the tank portions are formed in one side surface of each of the header tanks,

wherein each of the heat exchanging tubes has a flat configuration having a width dimension larger than a height dimension, and is provided with a plurality of refrigerant passages extending in a tube longitudinal direction and arranged in parallel in a tube widthwise direction,

wherein both ends of each of the heat exchanging tubes are communicated with the pair of header tanks so that the refrigerant passages of each of the heat exchanging tubes are grouped in the tube widthwise direction in accordance with each tank portion of the header tanks, to thereby form a plurality of passes arranged in parallel in the tube widthwise direction, and

wherein refrigerant passes through each of the grouped refrigerant passages independently.

In the fourth aspect of the present invention , since the fourth aspect of the present invention specifies a tube connecting structure for a header tank of a heat exchanger which is a principal portion of the heat exchanger according to the first aspect of the present invention, the aforementioned effects can be obtained.

In the fourth aspect of the present invention, in the same manner as in the first aspect of the present invention, it is preferable that end portions of the heat exchanging tubes are

provided with one or more cutout portions corresponding to the one or more partitioning walls, and the end portions of the heat exchanging tubes are inserted into the tube insertion apertures with the one or more partitioning walls fitted in the one or more cutout portions, or that one or more regions of each of the heat exchanging tubes corresponding to the one or more cutout portions are formed to be one or more non-passage areas in which no refrigerant passage exists, and wherein regions of each of the heat exchanging tubes not corresponding to the one or more cutout portions are formed to be passage areas in which the refrigerant passages exist.

The fifth aspect of the present invention specifies a refrigerant system using the heat exchanger according to the first aspect of the present invention.

According to the fifth aspect of the preset invention, a refrigerant system having a refrigeration cycle in which refrigerant compressed by a compressor is cooled by a gas cooler, decompressed by a decompressor, then heated while passing through a cooling device and then returned to the compressor,

wherein the gas cooler is configured by a heat exchanger comprising a pair of header tanks and a plurality of heat exchanging tubes disposed between the pair of header tanks and arranged in a header tank longitudinal direction,

wherein each of the header tanks is provided with one or more partitioning walls integrally formed in each of the header tanks and extended in the header tank longitudinal direction, whereby

a plurality of tank portions divided by the one or more partitioning walls and extended in the header tank longitudinal direction are formed so as to be arranged in parallel in a header tank widthwise direction, wherein a refrigerant turning communication aperture for communicating adjacent tank portions is formed in a prescribed partitioning wall,

wherein each of the heat exchanging tubes has a flat configuration having a width dimension larger than a height dimension, and is provided with a plurality of refrigerant passages extended in a tube longitudinal direction and arranged in parallel in a tube widthwise direction,

wherein both ends of each of the heat exchanging tubes are communicated with the pair of header tanks so that the refrigerant passages of each of the heat exchanging tubes are grouped in the tube widthwise direction in accordance with each tank portion of the header tanks, to thereby form a plurality of passes arranged in parallel in the tube widthwise direction, and

wherein refrigerant introduced into a first tank portion of one of the header tanks is introduced into a first tank portion of the other of the header tanks via a first pass, then the refrigerant is introduced into a second tank portion of the other of the header tanks via the refrigerant turning communication aperture, and thereafter the refrigerant is introduced into a second tank portion of the one of the header tanks via a second pass.

Since the fifth aspect of the present invention specifies a refrigerant system using the heat exchanger according to the first

aspect of the present invention, the similar effects as mentioned above can be obtained.

The fifth aspect of the present invention can be preferably employed as a refrigerant system using CO_2 refrigerant.

In the fifth aspect of the present invention, it is preferable that CO_2 is used as refrigerant.

The sixth aspect of the present invention specifies a gas cooler using supercritical refrigerant in which the heat exchanger according to the first aspect of the present invention is utilized.

According to the sixth aspect of the present invention, a gas cooler using supercritical refrigerant in which a plurality of heat exchanging tubes are disposed between a pair of header tanks and arranged in parallel in a header tank longitudinal direction,

wherein each of the header tanks is provided with one or more partitioning walls integrally formed in each of the header tanks and extended in the header tank longitudinal direction, whereby a plurality of tank portions divided by the one or more partitioning walls and extended in the header tank longitudinal direction are formed so as to be arranged in parallel in a header tank widthwise direction, wherein a refrigerant turning communication aperture for communicating adjacent tank portions is formed in a prescribed partitioning wall,

wherein each of the heat exchanging tubes has a flat configuration having a width dimension larger than a height dimension, and is provided with a plurality of refrigerant passages extended in a tube longitudinal direction and arranged in parallel

in a tube widthwise direction,

wherein both ends of each of the heat exchanging tubes are communicated with the pair of header tanks so that the refrigerant passages of each of the heat exchanging tubes are grouped in the tube widthwise direction in accordance with each tank portion of the header tanks, to thereby form a plurality of passes arranged in parallel in the tube widthwise direction,

wherein refrigerant introduced into a first tank portion of one of the header tanks is introduced into a first tank portion of the other of the header tanks via a first pass, then the refrigerant is introduced into a second tank portion of the other of the header tanks via the refrigerant turning communication aperture, and thereafter the refrigerant is introduced into a second tank portion of the one of the header tanks via a second pass, and

wherein the refrigerant passing through the first and second passes is cooled by exchanging heat with ambient air.

In the sixth aspect of the present invention, since the sixth aspect of the present invention specifies a gas cooler using supercritical refrigerant in which the heat exchanger according to the first aspect of the present invention is utilized, the similar effects as mentioned above can be employed.

The sixth aspect of the present invention can be preferably used as a gas cooler using CO_2.

In the sixth aspect of the present invention, it is preferable that CO_2 is used as the refrigerant.

In the present invention, "up and down direction" or "fore

and aft direction" are not defied based on gravity direction. For the explanatory purposes, the air introducing direction is defined as "fore and aft direction." In other words, the heat exchanger or the like according to the present invention is not limited in installation direction. For example, in the heat exchanger or the like according to the present invention, the longitudinal direction of the header tank can be disposed along any direction including horizontal direction, slant direction as well as vertical direction relative to the gravity direction.

Brief Description of Drawings

Fig. 1 is a perspective view showing a gas cooler using CO_2 refrigerant employed as a heat exchanger according to an embodiment of the present invention.

Fig. 2 is an exploded perspective view showing one of the header tanks and its vicinity of the gas cooler of the embodiment.

Fig. 3 is an exploded horizontal cross-sectional view showing the gas cooler of the embodiment.

Fig. 4 is an assembled horizontal cross-sectional view showing the gas cooler of the embodiment.

Fig. 5 shows an end portion of the heat exchanging tube employed in the gas cooler according to the present invention, wherein Fig. 5A is the plan view thereof and Fig. 5B is the end view thereof.

Fig. 6 is an exploded horizontal cross-sectional view showing the header tank and its vicinity of a gas cooler which is a modified

embodiment of the present invention.

Fig. 7 is an assembled horizontal cross-sectional view showing the header tank and its vicinity of a gas cooler which is the modified embodiment of the present invention.

Fig. 8 shows an end portion of the heat exchanging tube employed in the gas cooler according to the modified embodiment, wherein Fig. 5A is the plan view thereof and Fig. 5B is the end view thereof.

Fig. 9 is a schematic refrigerant circuit diagram showing the refrigerant flow of the gas cooler according to Example 1 relevant to the present invention.

Fig. 10 is a schematic refrigerant circuit diagram showing the refrigerant flow of the gas cooler according to Example 2 relevant to the present invention.

Fig. 11 is a schematic refrigerant circuit diagram showing the refrigerant flow of the gas cooler according to Comparative Example which is out of the scope of the present invention.

Fig. 12 is a graph showing the relationship between the refrigerant flow direction and the refrigerant temperature/cooling air temperature in the gas cooler according to the Examples.

Best Mode for Carrying Out the Invention

Fig. 1 is a perspective view showing a gas cooler applied to a heat exchanger according to an embodiment of the present invention, and Fig. 2 is an exploded perspective view showing one of the header tanks and its vicinity of the gas cooler. This heat exchanger is

employed in a refrigeration cycle using CO_2 refrigerant. As shown in Figs. 1 and 2, this heat exchanger is provided with a pair of right and left flat header tanks 10a and 10b disposed along an up and down direction, a plurality of flat heat exchanging tubes 30 disposed between the header tanks 10a and 10b and arranged in parallel in the header tank longitudinal direction (up and down direction) with the opposite ends thereof connected to the header tanks 10a and 10b in fluid communication, and corrugated fins each disposed between the adjacent upper and lower heat exchanging tubes 30, as fundamental structural elements.

As shown in Figs. 1 to 4, each of the header tanks 10a and 10b is an integrally formed metal article made of, for example, aluminum (including its alloy), and is provided with four tank portions, i.e., the first tank portion 11 to the fourth tank portion 14, extending in the header tank longitudinal direction. Between the adjacent tank portions 11 to 14, a partitioning wall 15 is formed, respectively, to thereby air-tightly partition the adjacent tank portions.

In the inner surface side of each of the header tanks 10a and 10b, corresponding to each of the tank portions 11 to 14, a plurality of tube insertion apertures 16 arranged at certain intervals in the longitudinal direction (in the up and down direction) are formed. Each tube insertion aperture 16 is formed into an elongated configuration extending in the header tank widthwise direction and communicated with the corresponding tank portion 11 to 14.

Between the adjacent upper and lower tube insertion apertures

16 at the inner surface side of one of the header tanks 10a, refrigerant turning communication apertures 17 are formed by cutting out the partitioning wall 15 partitioning the second and third tank portions 12 and 13. With these refrigerant turning communication apertures 17, the second and third tank portions 12 and 13 are in fluid communication with each other, so that refrigerant can flow from the second tank portion 12 to the third tank portion 13.

Furthermore, at the longitudinal middle portion of the rear side of one of the header tanks 10a, a refrigerant inlet 1 communicating with the first tank portion 11 is formed, while at the longitudinal middle portion of the front side thereof, a refrigerant outlet 2 communicating with the fourth tank portion 14 is formed.

Between the adjacent upper and lower tube insertion apertures 16 at the inner surface side of the other of the header tanks 10b, refrigerant turning communication apertures 17 are formed by cutting out the partitioning wall 15 partitioning the first and second tank portions 11 and 12 and the partitioning wall 15 partitioning the third and fourth tank portions 13 and 14. With these refrigerant turning communication apertures 17, the first and second tank portions 11 and 12 and the third and fourth tank portions 13 and 14 are in fluid communication with each other, respectively, so that refrigerant can flow from the first tank portion 11 to the second tank portion 12 and the third tank portion 13 to the fourth tank portion 14, respectively.

As shown in Figs. 1 and 2, at the upper and lower end portions of the inner surface side of each of the header tanks 10a and 10b, a closing slit 18 is formed by cutting in the tank widthwise direction (in the fore and aft direction) so as to cross all of the tank portions 11 to 14 in the widthwise direction thereof, respectively. In each closing slit 18, a closing plate 19 is fitted in and brazed thereto. Thus, the upper and lower end portions of each tank portion 11 to 14 of each of the header tank portions 10a and 10b are air-tightly sealed by the closing plate 19, respectively.

As shown in Figs. 1 to 4, a joining plate 20 is brazed to the inner surface of each of the header tanks 10a and 10b so as to close the refrigerant turning communication apertures 17. This joining plate 20 is provided with a plurality of tube insertion apertures 21 corresponding to the tube insertion apertures 16 of the header tank 10a and 10b arranged at certain intervals in the longitudinal direction (i.e., in the up and down direction).

In this embodiment, the header tanks 10a and 10b can be formed by extrusion processing or drawing processing.

In detail, after forming a tank intermediate having tank portions 11 to 14 by extrusion processing or drawing processing, the tube insertion apertures 16, the refrigerant turning communication apertures 17 and the closing slits 18 are formed by subjecting the tank intermediate to cutting processing, to thereby obtain the header tanks 10a and 10b. By integrally forming the partitioning walls 15 in each of the header tanks 10a and 10b by

extrusion processing, the air-tightness of the partitioning walls 15 can be improved, resulting in sufficient pressure resistance.

In this embodiment, cutting processing executed to each of the header tanks 10a and 10b, i.e., cutting processing to form the tube insertion apertures 16, cutting processing to form the refrigerant turning communication apertures 17 and cutting processing to form the closing slits 18, are simultaneously performed to decrease the number of processing steps and improve the manufacturing efficiency.

Furthermore, in this embodiment, after the aforementioned cutting processing, it is preferable that the inner surface of each of the header tanks 10a and 10b, i.e., the joining surface to which the joining plate 20 is joined, is subjected to milling processing to obtain a flat and smooth surface. By forming the inner surface of each of the header tanks into such a flat and smooth surface, the joining area of the joining plate 20 to be integrally joined to the inner surface can be kept larger, causing improved joining degree(adherence degree) and increased strength, which in turn can further improve the pressure resistance.

The aforementioned joining plate 20 can be formed by, for example, calendaring processing, extruding processing or drawing processing. In detail, the joining plate 20 can be formed by subjecting the plate-shaped intermediate to cutting or drilling processing to form the tube insertion apertures 21 after forming a plate-shaped intermediate made of metal such as aluminum (including its alloy).

Needless to say, in the present invention, the processing methods of the header tanks 10a and 10b and the joining plates 20 are not limited to the above.

As shown in Figs. 2 to 5, each of the heat exchanging tubes 30 is constituted by an extruded article or a drawn article made of metal such as aluminum (including its alloy), and has a flat cross-sectional configuration. In the heat exchanging tube 30, a plurality of refrigerant passage 35 each extending in the longitudinal direction and having a rectangular cross-section are arranged in parallel in the tube widthwise direction.

The refrigerant passages 35 are grouped into a total of four passage groups in the tube widthwise direction corresponding to the first to fourth tank portions 11 to 14 of the header tanks 10a to 10b. The refrigerant passages 35 of each of the four passage groups constitute the first pass P1 to the fourth pass P4 in this order from the rear side.

Furthermore, in the non-refrigerant-passage-forming regions of the end portions of each heat exchanging tube 30 in which no refrigerant passage is formed, in other words, in the regions of the end portions between adjacent passes P1 to P4, a cutout portion 36 is formed, respectively. Fitted to the cutout portions 36 are the corresponding regions of the joining plate 20 located between the adjacent tube insertion apertures 21 arranged in the fore and aft direction (in the widthwise direction) and the corresponding partitioning walls 15 of the header tank 10a and 10b. Thus, the refrigerant-passage-forming regions of each end portion of the heat

exchanging tube 30, i.e., the regions in which the passes P1 to P4 are formed, are inserted into the tube insertion apertures 21 of the joining plate 20 and the tube insertion apertures 16 of each of the header tanks 10a and 10b.

Thus, a plurality of heat exchanging tubes 30 are disposed between the pair of header tanks 10a and 10b and arranged in parallel at certain intervals in the up and down direction with the opposite ends thereof connected to the pair of header tanks 10a and 10b disposed along the up and down direction via the joining plate 20. In this state, the required portions thereof are integrally brazed.

Thus, the first to fourth passes P1 to P4 of each heat exchanging tube 30 are arranged in parallel within a plan in this order from the rear side.

Between the adjacent heat exchanging tubes 30, a corrugated fin 40 made of metal such as aluminum (including its alloy) is disposed. In this state, the required portions are integrally brazed.

A refrigerant inlet pipe 51 is connected to the refrigerant inlet 1 of one of the header tanks 10a in fluid communication and integrally brazed thereto, while a refrigerant outlet pipe 52 is connected to the refrigerant outlet 2 of the other of the header tanks 10a in fluid communication and integrally brazed thereto.

In the aforementioned gas cooler according to this embodiment, although components are made of aluminum or its alloy as mentioned above, they can be made of aluminum brazing sheets with brazing materials laminated on at least one surface. These components are

provisionally assembled into a prescribed gas cooler configuration via brazing materials. Then, this entire provisional product is brazed in a furnace to thereby obtain an integrally joined product.

In the present invention, in assembling the heat exchanger, partial brazing can be employed or a combination of partial brazing and entire brazing can be employed. Any assembling method can be employed.

The gas cooler configured as mentioned above constitutes a refrigeration cycle using CO_2 together with a compressor, a decompression expanding device and a cooler, and forms a refrigerant system for use in car air-conditioners. In this refrigerant system, an outlet side of the compressor is connected to the refrigerant inlet pipe 51 of the gas cooler, while the refrigerant outlet pipe 52 is connected to an inlet side of the decompression expanding device.

In this refrigeration system, CO_2 refrigerant compressed by a compressor is introduced into the first tank portion 11 of one of the header tanks 10a of the gas cooler via the refrigerant inlet pope 51.

The refrigerant introduced into the first tank portion 11 of one of the header tanks 10a passes through the first pass P1 and then introduced into the first tank portion 11 of the other of the header tanks 10b. Then, the refrigerant is introduced into the second tank portion 12 in the header tank 10b via the refrigerant turning communication apertures 17.

The refrigerant introduced into the second tank portion 12

of the other of the header tanks 10b passes through the second pass P2 and then introduced into the second tank portion 12 in the one of the header tanks 10a. Thereafter, the refrigerant is introduced into the third tank portion 13 of the header tank 10a via the refrigerant turning communication apertures 17.

The refrigerant introduced into the third tank portion 13 of the one of the header tanks 10a passes through the third pass P3, then introduced into the third tank portion 13. Thereafter, the refrigerant is introduced into the fourth tank portion 14 of the header tank 10b via the refrigerant turning communication apertures 17.

The refrigerant introduced into the fourth tank portion 14 of the other of the header tanks 10b passes through the fourth pass P4, and then introduced into the fourth tank portion 14 of the one of the header tanks 10a. Thereafter, the refrigerant flows out via the refrigerant outlet pipe 52.

As mentioned above, the refrigerant exchanges heat with the cooling air A introduced from the front side of the gas cooler while passing through the first to fourth passes P1 to P4 in this order, to be gradually cooled.

The cooling air A is introduced from the front side of the gas cooler and passes from the fourth pass P4 toward the first pass P1 in this order to cool the refrigerant in each pass. The cooling air is gradually increased in temperature, and then discharged from the rear side of the gas cooler. On the other hand, the refrigerant passes the first pass P1 to the fourth pass P4 from the rear side

in this order, and is gradually decreased in temperature. That is, the refrigerant of high temperature immediately after being introduced into the gas cooler exchanges heat with the air A of relatively high temperature immediately before being discharged, while the refrigerant of low temperature immediately before being discharged exchanges heat with the air A of low temperature immediately after being introduced into the gas cooler. Therefore, the refrigerant can keep an appropriate temperature difference relative to the air A in all of the passes P1 to P4, causing efficient heat exchanging, which enables excellent heat exchanging performance.

The cooled refrigerant is decompressed and expanded by a decompression expanding device to be cooled. Thereafter, the refrigerant cools the air in an automobile via a cooling device while being heated, and then returns to a compressor.

As mentioned above, the gas cooler of this embodiment has a counter flow type refrigerant circuit in which refrigerant is forced to flow against the introducing direction of the cooling air A. Therefore, an appropriate temperature difference between the refrigerant and the cooling air A can be kept through the entire circuit from the starting of cooling the refrigerant to the ending of cooling the refrigerant, causing efficient heat exchanging, which enables excellent heat exchanging performance.

Furthermore, in the gas cooler according to this embodiment, each of the header tanks 10a and 10b is constituted by an integrally formed article formed by extrusion processing and the partitioning

walls 15 are integrally formed thereto. Therefore, the air-tightness of the partitioning walls 15 can be assuredly secured while obtaining enough pressure resistance. Furthermore, a mixture of refrigerant due to leakage at the partitioning walls 15 can be prevented, resulting in excellent heat exchanging performance.

Furthermore, since the heat exchanging tube 30 is constituted by an integrally formed article formed by extrusion processing, enough pressure resistance of the heat exchanging tube can be obtained.

Furthermore, since the header tanks 10a and 10b and the heat exchanging tubes 30 are formed by extrusion processing which is excellent in mass production, the manufacturing efficiency can be improved.

In this embodiment, since the end portions of each heat exchanging tube 30 are inserted into the header tanks 10a and 10b and then secured thereto, the stable brazing can be attained. This enables to improve the pressure resistance while preventing generation of joining defects.

Furthermore, in this embodiment, cutout portions 36 are formed in the end portions of the heat exchanging tube 30, and the heat exchanging tube 30 is secured to the header tanks 10a and 10b with the partitioning walls 15 engaged with the cutout portions 36. Therefore, this engaging enables accurate positioning of the tube end portions in the insertion direction and in a direction perpendicular to the insertion direction and easy insertion

operation of the tube 30. Furthermore, an enough joining area of the tube 30 relative to the header tank 10a and 10b can be secured, enabling an stably secured state, which in turn further improves the pressure resistance while assuredly preventing generation of joining defects.

Furthermore, in this embodiment, since the cutout portions 36 are formed in the non-passage-forming regions of the end portions of the heat exchanging tube 30 in which no refrigerant passage is formed, it is assuredly prevented that the cutout portions 36 are formed in the regions in which refrigerant passages 35 are formed.

Furthermore, in this embodiment, since the inner surface side of the header tank 10a and 10b is subjected to cutting processing to thereby form the refrigerant turning communication apertures 17 communicating with adjacent tank portions, the forming of the apertures 17 can easily be performed.

Furthermore, in this embodiment, since the forming of the communication apertures 17 are performed simultaneously with the forming of the tube insertion apertures 16 and/or the forming of the closing splits 18, the number of processing steps can be decreased, enabling efficient boring processing, which in turn can further improve the manufacturing efficiency.

Furthermore, in this embodiment, since the header tank 10a and 10b is reinforced by securing a joining plate 20 to the inner surface side of the header tank, the pressure resistance can be further improved.

Furthermore, since the communication apertures 17 of the

header tank 10a are closed in a sealed manner by securing the joining plate 20, the sealing operation of the communication apertures can be eliminated, resulting in further improved manufacturing efficiency.

In this embodiment, although the cutout portions 36 are formed at the end portions of each heat exchanging tube 30 and engaged with the portions between the tube insertion apertures of the joining plate 20 and the partitioning walls 15 of the header tanks 10a and 10b, the present invention is not limited to it.

For example, the structure as shown in Figs. 6 to 8 can be employed. In this structure, protrusions 36 are formed at the non-passage-forming portions of the end portions of the heat exchanging tube 30, while a tube insertion aperture 21 continuously extending in the widthwise direction is formed in the joining plate 20. Further, a tube insertion aperture 16 communicating with the four tank portions 11 to 14 is formed at the inner surface side of the header tank 10a and 10b. Corresponding to the tube insertion aperture 16, penetrated apertures 16a are formed by cutting the partitioning walls 15 of the header tank 10a and 10b. The end portion 36 of the heat exchanging tube 30 is inserted into the tube insertion aperture 21 of the joining plate 20 and the tube insertion aperture 16 of the header tank 10a and 10b, while the protruded end portions 36 of the tube are fitted in the penetrated apertures 16a. In this state, these members are integrally secured by brazing the necessary portions.

In this heat exchanger (gas cooler), as mentioned above, the

heat exchanging tubes 30 and the header tanks 10a and 10b can be secured in a stable manner, resulting in sufficient pressure resistance.

In the aforementioned embodiment, a four-pass type gas cooler having four passes P1 to P4 is exemplified. However, the present invention is not limited to this, and can be applied to a heat exchanger having two or more passes.

<Example 1>

As shown in Fig. 9, in the same manner as in the aforementioned embodiment, a four-pass counter flow type gas cooler using CO_2 refrigerant (see Fig. 1) in which the first pass P1 to the fourth pass P4 are formed within a plane parallel to the introducing direction of air A in a meandering manner in this order against the introducing direction of the air A from the downstream side of the air toward the upstream side thereof was prepared.

<Example 2>

As shown in Fig. 10, a two-pass counter flow type gas cooler using CO_2 refrigerant in which the first pass P1 and the second pass P2 are formed within a plane parallel to the introducing direction of air A in a meandering manner in this order against the introducing direction of the air A from the downstream side of the air toward the upstream side thereof was prepared.

<Comparative example>

As shown in Fig. 11, a four-pass cross flow (multi-flow) type gas cooler using CO_2 refrigerant in which the first pass P1 to the fourth pass P4 are formed within a plane perpendicular to the

introducing direction of the air A in a meandering manner in this order from the upper side toward the lower side was prepared.

These gas coolers were operated in a refrigeration system, and the refrigerant flowing positions (distances L in the refrigerant passages from the inlet), the refrigerant temperature and the cooling air temperature T were measured. The results are shown in the graph in Fig. 12.

In this graph, the black filled square mark denotes the refrigerant temperature in Example 1, the while blank square mark denotes the cooling air temperature in Example 1, the black filled triangle mark denotes the refrigerant temperature in Example 2, the white blank triangle mark denotes the cooling air temperature in Example 2, the black filled circle mark denotes the refrigerant temperature in Comparative Example 1, and the while blank circle mark denotes the cooling air temperature in Comparative Example 1.

As will be apparent from this graph, in the gas coolers of Example 1 and Example 2, the temperature difference between the refrigerant whose temperature decreases gradually as it travels along the refrigerant passage and the cooling air could be secured sufficiently in the entire refrigerant passage (all passes), and therefore the refrigerant was cooled efficiently.

To the contrary, in the gas cooler of Comparative Example, the temperature difference between the refrigerant and the cooling air varied widely in the refrigerant passage. Especially, at the refrigerant outlet and therearound, the temperature difference

between the refrigerant and the cooling air became small, and therefore it was difficult to effectively cool the refrigerant.

In the gas coolers of Example 1 and Example 2, there was no gas leakage at the partitioning wall portions in the header tank and the joint portions between the header tank and the heat exchanging tubes and no refrigerant mixture.

The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intent, in the use of such terms and expressions, of excluding any of the equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

Industrial Applicability

The heat exchanger, the manufacturing method, the tube connecting structure of a heat exchanger header tank, the gas cooler using supercritical refrigerant and the refrigerant system can be employed as, for example, automobile air-conditioners, household air-conditioners, cooling devices for electric devices having a refrigeration cycle using CO_2 refrigerant.